Could a Massless SU(5) Theory Underly the Standard Model ? {*Big X-Section New LHC Physics is Predicted !*} *

Using supercritical RFT, I have argued that the **uniquely unitary*** **Critical $\mathbb{P}$** *occurs* {*via anomaly dynamics*} *in* **"QCD$_S$" = QCD$_{n_f=6}$** + {**a sextet quark doublet**} $\longrightarrow$

EW sym-breaking {sextet pions} **&**
Dark Matter {stable sextet neutrons}

(Anomaly color factors => big $\mathbb{P}$ x−sections for EW bosons & sextet nucleons − at the LHC ?)

Remarkably, QCD$_S$ *embeds* **uniquely** *in* **"QUD"** * - *a* **massless** *SU(5) theory that, even more remarkably, may have (via massless fermion IR anomalies) a* **bound-state S-Matrix that reproduces the full Standard Model.**

* The RFT Critical $\mathbb{P}$ (alone) satisfies all high−energy unitarity constraints.
* Quantum Uno/Unification/Unique/Unitary/Underlying Dynamics

* Presented at Gribov−80, May 2010, Trieste, Italy

QUD $\longleftrightarrow$ **SU(5)** *gauge theory with* **massless, left-handed,** *fermions in the*

$\mathbf{5} \oplus \mathbf{15} \oplus \mathbf{40} \oplus \mathbf{45}^*$ *representation.*

Uniquely *discovered as* **1) anomaly free 2) asymptotically free** $\{$*just*$\}$ **& 3) contains the EW symmetry-breaking sextet sector.** *Under* $SU(3) \otimes SU(2) \otimes U(1)$

$$\mathbf{5}=(\mathbf{3},\mathbf{1},-\tfrac{\mathbf{1}}{\mathbf{3}}))^{\{\mathbf{3}\}}+(\mathbf{1},\mathbf{2},\tfrac{\mathbf{1}}{\mathbf{2}})^{\{\mathbf{2}\}}\ , \qquad \mathbf{15}=(\mathbf{1},\mathbf{3},\mathbf{1})+(\mathbf{3},\mathbf{2},\tfrac{\mathbf{1}}{\mathbf{6}})^{\{\mathbf{1}\}}+(\mathbf{6},\mathbf{1},-\tfrac{\mathbf{2}}{\mathbf{3}})\ ,$$

$$\mathbf{40}=(\mathbf{1},\mathbf{2},-\tfrac{\mathbf{3}}{\mathbf{2}})^{\{\mathbf{3}\}}+(\mathbf{3},\mathbf{2},\tfrac{\mathbf{1}}{\mathbf{6}})^{\{\mathbf{2}\}}+(\mathbf{3}^*,\mathbf{1},-\tfrac{\mathbf{2}}{\mathbf{3}})\ +\ (\mathbf{3}^*,\mathbf{3},-\tfrac{\mathbf{2}}{\mathbf{3}})+(\mathbf{6}^*,\mathbf{2},\tfrac{\mathbf{1}}{\mathbf{6}})+(\mathbf{8},\mathbf{1},\mathbf{1})\ ,$$

$$\mathbf{45}^*=(\mathbf{1},\mathbf{2},-\tfrac{\mathbf{1}}{\mathbf{2}})^{\{\mathbf{1}\}}+(\mathbf{3}^*,\mathbf{1},\tfrac{\mathbf{1}}{\mathbf{3}})+(\mathbf{3}^*,\mathbf{3},\tfrac{\mathbf{1}}{\mathbf{3}})+(\mathbf{3},\mathbf{1},-\tfrac{\mathbf{4}}{\mathbf{3}})+(\mathbf{3},\mathbf{2},\tfrac{\mathbf{7}}{\mathbf{6}}))^{\{\mathbf{3}\}}+(\mathbf{6},\mathbf{1},\tfrac{\mathbf{1}}{\mathbf{3}})+(\mathbf{8},\mathbf{2},-\tfrac{\mathbf{1}}{\mathbf{2}})$$

Not only does **QUD** *contain* **QCD**$_S$, *both the triplet quark & lepton sectors* $\{$*not asked for*$\}$ *are amazingly close to the SM !!! There are three "generations"* $-$ $\{1\},\{2\},\{3\}$.

Very importantly, **QUD is real** $\{$*vector-like*$\}$ **wrt SU(3)xU(1)**$_{em}$**.** *SU(2)xU(1) is not quite right* **but the lepton anomaly is correct** $=>$ *to be physically realistic,*

all elementary leptons & quarks must be confined & massless !!

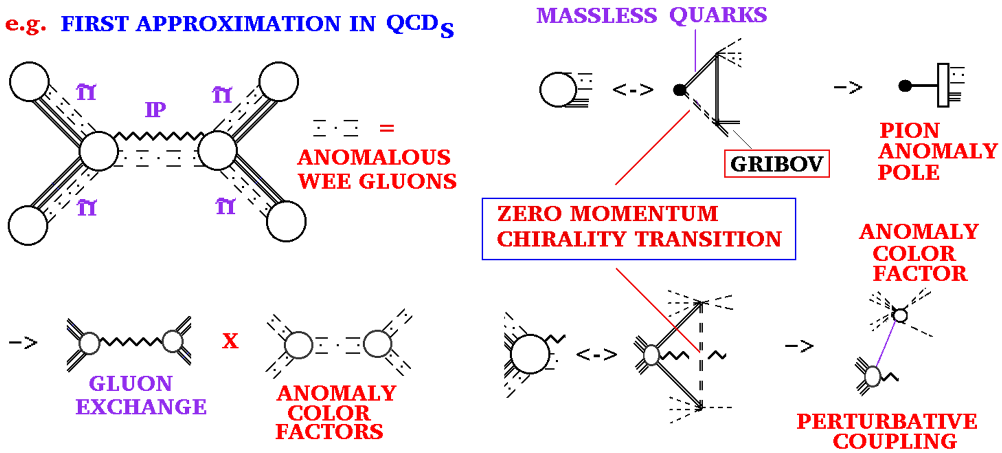
As for QCD$_S$, *access to the QUD bound-state S-Matrix is provided by multi-regge theory !!!*

The multi-regge region *involves multiple ∞-momenta that* $\{$*fundamentally*$\}$ *allow* **wee partons** *to (simultaneously) play a* **vacuum role in both states & interactions.**

I will build up the multi-regge QUD S-Matrix via IR divergences, by removing masses, & a $k_\perp$ cut-off, in perturbative **reggeon diagrams.**

In massless* QCD$_S$ - Anomalies + IR fixed pt. $\longrightarrow$ IR divergence $\longrightarrow$ *Wee gluons in all bound-states & interactions - coupled via* **zero-momentum quark chirality transitions,**

e.g. FIRST APPROXIMATION IN QCD$_S$



$\longrightarrow$ Confinement & chiral sym brkg

$+$ parton model $\{$in coexistence !!$\}$

$\longrightarrow$ Quark hadrons $\longleftrightarrow$ no glueballs

$+$ additive quark model for σ_{tot}.

$\rightarrow$ large sextet v. triplet anomaly color factor

$\longrightarrow$ **Critical $\mathbb{P}$** $\{$regge pole + $\mathbb{P}\mathbb{P}\mathbb{P}\}$

*Many massless mesons $\longrightarrow$ S$-$Matrix $\{???\}$. Masses require QUD.

S-Matrix IR chirality transitions *play an even more fundamental role in QUD. (They are produced by the zero fermion mass limit of reggeon anomaly vertices.)*

Although only an outline, for which $\{$*as will be obvious*$\}$ *much further development* is needed and many details are missing, my construction will imply the following.

1. **All elementary fermions are confined.** *Bound-states are formed by anomaly poles*

   the symmetry breaking SU(5) $\longrightarrow$ **SU(3)**$\otimes$**U(1)**$_{em}$
   is due to **zero-momentum chirality transitions.**

2. **Interactions are vector boson reggeons + anomalous wee gauge bosons.**

3. **Symmetry-breaking is an S-Matrix phenomenon** $\longleftrightarrow$ **no off-shell amplitudes (?)**

   SU(5) is unbroken at large $k_\perp$ *but, although QUD lies in the "conformal window",*

   the S-Matrix has only SM interactions & a spectrum of SM form.

4. **All particles (including neutrinos) are bound-states with dynamical masses.**

There is no Higgs !!

Because of it's uniqueness, QUD is either right or wrong - in it's entirety.
$\{$**To be right**$\}$ **it must reproduce the full Standard Model S-Matrix !!**

{*Motivated by a unitary* $\mathbb{P}$ *!!*} **QUD could provide a remarkably economic unification** *& even* {*perhaps*} *an origin** *for the SM.* *Beyond the SM generations, there is* **only**

1. *A* **sextet quark sector** *that minimally, & naturally, solves two major mysteries*
   Sextet pions $\longrightarrow$ $W^{\pm}, Z^0$ **masses, & stable* sextet neutrons** $\longrightarrow$ **dark matter !**
2. *A "lepton-like"* **octet quark sector** *that is buried in all states as UV anomaly poles*

   $\longrightarrow$ **leptons & hadrons in SM generations**
3. *A pair of exotically charged quarks.*

Nothing else !!

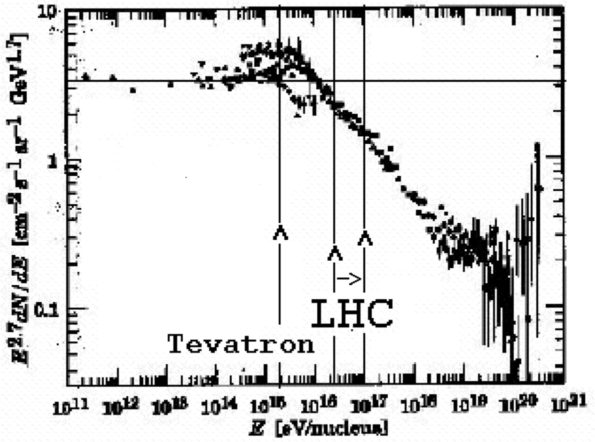
Although the physics is both **novel & radical, the outcome is simple, consistent with established SM physics, & explains many puzzles.** *But, the multi-regge theory that I use to uncover it is so erudite that general interest will probably require (what would surely be)*

A MAJOR EXPERIMENTAL DISCOVERY

LHC please discover asap !! $\left\{\begin{array}{c}\textbf{BIG x-sections for}\\ \textbf{multiple } \mathbf{Z'}\textbf{s \& } \mathbf{W'}\textbf{s, } \mathbf{N_6} \textbf{ \& } \mathbf{P_6}\\ \textbf{pairs, \&, distinctively,} \gamma\mathbb{P} \rightarrow Z\\ \textbf{double } \mathbb{P} \rightarrow ZZ,\ WW \textbf{ pairs}\end{array}\right\}$

* **Possibly, the SM (within QUD) is THE unique unitary particle S−Matrix !!**
* **Sextet protons are unstable − decaying to sextet neutrons.**

COSMIC RAYS already suggest that new large x-section physics including dark matter could appear at the LHC !!



The spectrum knee occurs between Tevatron and LHC energies. It is remarkably well-established, yet not understood. Although dark matter was unknown, a major threshold for **neutral particles,** *unobserved in detectors, was initially suggested* $\{\sim$ *40 years ago !* $\}$. *Underestimation of the energy would pile-up events as a "knee".*

If the dark matter x-section is large at the LHC, a link to the knee is surely inevitable !!

For the sextet sector **three effects** should combine to produce a knee.

1. **Prolific production of EW bosons increases $<p_\perp>$ dramatically (& increases neutrino production) − leading to energy underestimation.**
2. **Threshold production of sextet neutron dark matter $\{\leftrightarrow$ inclusive $\mathbb{P}\}$.**
3. **Sextet neutrons as (UHE?) incoming cosmic rays with a ($\mathbb{P}$) threshold for atmospheric interaction not far below the knee.**

X-sections must be **BIG** *& at UHE must dominate* σ_{tot} $\left\{ \begin{array}{l} \Rightarrow \text{Dark Matter dominates} \\ \text{early universe x-sections ??} \end{array} \right\}$

Related $\{$**crucial**$\}$ **questions.** $\left\{ \begin{array}{l} \textbf{i) Can MASSLESS QUD produce SM scales?} \\ \textbf{ii) Why should the sextet sector have BIG x-sections?} \end{array} \right\}$

An IR fixed-pt $\Longrightarrow$ α_{QUD} **is very small** $\lesssim \frac{1}{120}$ $(\mathbf{QUD\ is\ nearly\ conformal\ !})$

$\Longrightarrow$ **SM couplings** $\not\longleftrightarrow$ **QUD evolution** $\{\equiv \mathbf{no\ off\!-\!shell\ amplitudes}\}$

But, $\{$most likely$\}$ $\Longrightarrow$ **very small mass neutrinos** (no color/electric charge).

All particles are bound-states $\Longrightarrow$ α_{QUD} **has no physical meaning.**

S-Matrix amplitudes are selected by an IR divergence $\longrightarrow$

- *Physical states & amplitudes all contain infinite sums of wee gauge bosons involving* **anomaly color factors** $\{\mathbf{expressed,\ presumably,\ as\ integral\ formulae}\}.$

  $\Longrightarrow$ *All interaction strengths are enhanced, with the* **SU(3) interaction strongly amplified by both color factors & the triple** $\mathbb{P}$ **interaction** $\{\mathbf{see\ later}\}$**.**

- $\mathbb{P}$ *anomaly color factors imply high-energy sextet x-sections are* **much larger** *than triplet x-sections* $=>$ **Dark Matter dominates early universe x-sections** *??*

My analysis of QUD anomaly dynamics relies fundamentally on multi-regge theory. $\Big\}$ To give an outline, I begin with some basics - a regge pole gives

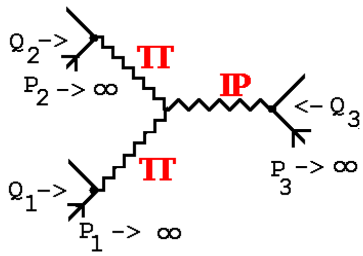
$$A^{+}(s,t) \underset{s\to\infty}{\sim} f(t)\,\frac{s^{\alpha(t)}}{sin\,\frac{\pi}{2}\,\alpha(t)} \quad \Longrightarrow$$

t- channel bound-state poles $\big(at\ \alpha(t)=0,2,\ldots\big)$ can be discovered

by calculating the $s \to \infty$ (∞-momentum limit) in the cross-channel.

In multi-regge limits multiple regge poles appear, e.g.

the triple regge limit ->



$P_1, P_2, P_3 \to \infty$ along distinct light-cones.

In the P_3 rest-frame, the bound-state regge pole pions also have ∞-momentum.

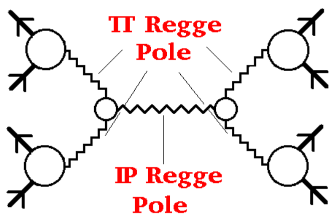
Continuation to $Q_1^2 = Q_2^2 = m_\pi^2$ gives the on-shell pion amplitude for $\mathbb{P}$ exchange.

A priori, at ∞-momentum, **wee partons** *could play a* **vacuum** *role* in bound-states* **- if they are "universal".** *We will see that indeed, in QUD, multi-regge reggeon diagrams do produce "vacuum wee partons", but we must first introduce further ∞-momenta* **!!**

* $\mathbf{c.f.\ light-cone\ quantization\ using\ the\ perturbative\ vacuum.}$

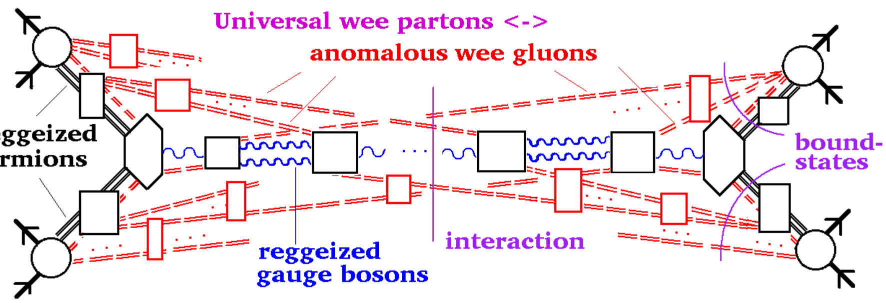
In the **"di-triple regge"** *(DTR) limit two triple-regge limits are separated by a further ∞-momentum. Now, regge-pole $\pi's$ can scatter via the $\mathbb{P}$. All the $\pi's$ & the $\mathbb{P}$ have ∞-momentum in some frame*

Hadron DTR Amplitude



=> both bound-states ($\pi's$) & interactions ($\mathbb{P}$) could appear as parton (reggeon) states **if universal** *wee reggeons carry vacuum properties* $\{>> parton\ model\}$. *We will see that, in QUD, an initial divergence produces* **"anomalous wee gluons" universally !!**

Multiple wee parton interactions in a typical initial QUD DTR Amplitude



That SM states & interactions {& the Critical P} emerge from such diagrams *as the complexity increases,* **is what has to be demonstrated !!**

Reggeon Diagrams {a crash course} -

1. **In (multi-)regge limits the large light-cone momenta are routed through feynman diagrams so that internal particles are maximally close to mass-shell & have large relative rapidities.**

   $\longrightarrow$ $k_\perp$ **diagram integral (**$\leftrightarrow$ **close to on-shell lines contracted)**

   multiplied by rapidity logarithms.

2. *Summing rapidity logarithms via reggeon propagators* $\longrightarrow$ *reggeon diagrams.*
   $\{$ Infinitely many feynman diagrams $\longleftrightarrow$ 1 reggeon diagram $\}$

3. *Internal particles with finite relative rapidity* $\longrightarrow$ *couplings with more structure, including* **fermion loop interactions.**

4. *In a gauge theory* **triangle anomalies** *occur but* $\{$*because a four-dimensional interaction is involved*$\}$ *only in* **special vertices** *coupling distinct reggeon channels* **- not*** *in the single channel reggeon diagrams describing large* $k_\perp$ *amplitudes.*

*SU(5) symmetry is not violated at "short distances" in QUD.

Reggeon anomaly vertices *include axial-vector/vector/vector triangle diagrams* T^{AVV} *that,* **in QUD, must be defined at zero mass.** *At first sight,*

- **chirality is conserved at zero mass** $\Longrightarrow$ $T^{AAA} = T^{AVV} = T^{RRR} + T^{LLL}$

  $\Longrightarrow$ *a conflict between the axial-vector anomaly & vector current conservation.*

  But, regularization of γ_5 amplitudes is a major issue !!

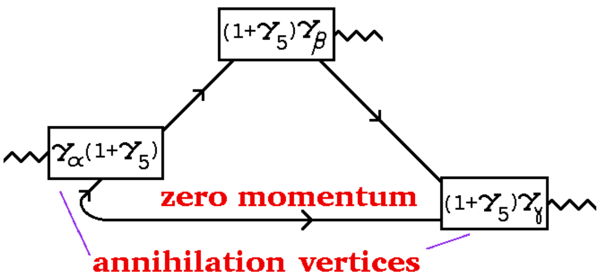
- *Fortunately,* $\{$*it can be shown that*$\}$ **vector current conservation + axial anomaly**

  $\Longrightarrow$ **unique massless anomaly pole amplitudes** $\Longrightarrow$

IR pseudoscalar anomaly poles appear similiarly in both non chirality-violating & chirality-violating amplitudes via the triangle singularity.

e.g.

T^{LRR}



Two annihilation vertices $\leftrightarrow$ *zero momentum chirality violation* $\Longrightarrow$ *the pseudoscalar pole can be a chiral Goldstone boson.*

UV chirality transitions similarly produce anomaly poles as part of a Pauli−Villars subtraction when $\lambda_\perp \to \infty$.

I use QUD reggeon diagrams to construct small $k_\perp$ DTR amplitudes*.

- *I start with massive reggeons, via scalar VeV's, & with a $k_\perp$ cut-off $\lambda_\perp$*
  $\{$**VeV fermion masses, necessarily, identify particle/antiparticle pairs.**$\}$
- *Because IR divergences produce wee partons in the massless theory, how the masses are removed is crucial. Anomalies play a key role* $\{$**via the Gribov ambiguity**$\}$.

I take limits as follows -

1. *Fermion masses* $\{\mathbf{24}$ *&* $\mathbf{5} \oplus \mathbf{5}^*$ *VeV's*$\}$ *are removed first, leaving* **chirality transitions** *in* **anomaly vertices** *that* **conserve SU(3)$\otimes$U(1)$_{em}$** *but* **not SU(5).**

2. *For gauge bosons,* $\mathbf{5} \oplus \mathbf{5}^*$ *VeV's* $\longrightarrow$ *smooth massless limit* $\{$**complimentarity**$\}$ *Exponentiation of reggeization divergences confines* global SU(5), leaving IR finite interaction kernels. I take the limit in stages*

$$\longrightarrow \text{SU(2)}_C, \quad \longrightarrow \text{SU(4)}, \quad \underset{\text{asymptotic freedom}}{\lambda_\perp \longrightarrow \infty}, \quad \longrightarrow \text{SU(5)} \quad \underset{\text{Supercritical} \to \text{Critical P}}{\left(\text{SU(2)}_C \longrightarrow \text{SU(3)}_C\right)}$$

***Very different from the large $k_\perp$ use of QCD diagrams in BFKL physics.**
***Not true confinement! Multi−gluon singularities remain.**

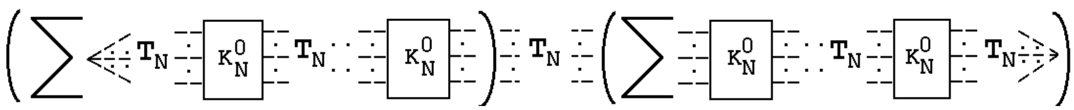
Because of $\lambda_\perp$, fermion loops do not have Ward identity zeroes when subsets of reggeon momenta vanish $=>$ **many new divergences** *that exponentiate amplitudes to zero* $\{\mathbf{including\ most\ left-handed\ boson\ couplings}\}$.

The first color restoration $\leftrightarrow$ **(vector) SU(2)$_C$** $\longrightarrow$ *a wee gluon divergence that* **couples only via anomaly vertices** *& so* **does not exponentiate** $\longleftrightarrow$

"anomalous wee gluons" $\Bigg\{$ **Sets of massless reggeized gluons, with all $k_\perp$'s scaled to zero - with $I = 0$ &** *"anomalous"* **color parity C $\neq \tau =$ signature.** $\Bigg\}$

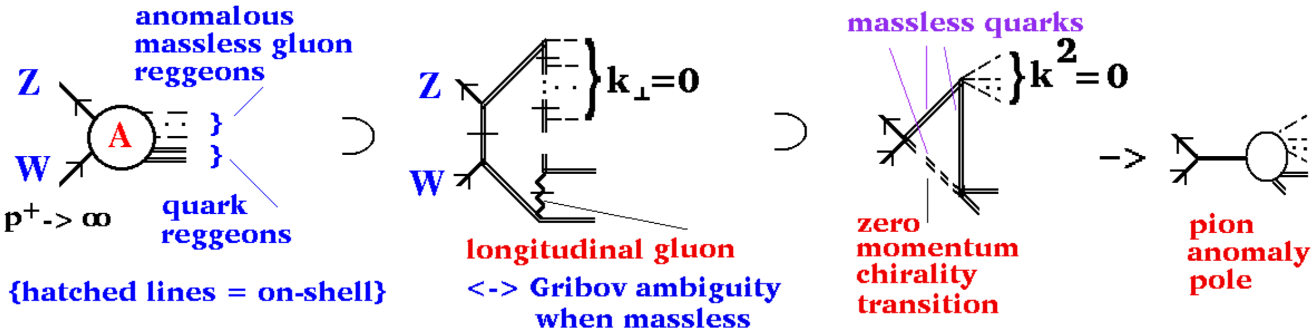
For SU(2), only $\tau = -C{=}-1$ is possible $\leftrightarrow$ $3, 5, \ldots \infty$ *gluon reggeons.*

IR fixed-point scaling $\Longrightarrow$ *iteration of $I = 0$ reggeon kernels reproduces the basic divergence with a* factorized residue. Factorizing off the divergence



$\longrightarrow$ **universal wee gluon component of reggeon states & interactions.**

The divergence also produces **bound-state anomaly poles** *in vertices, e.g.*



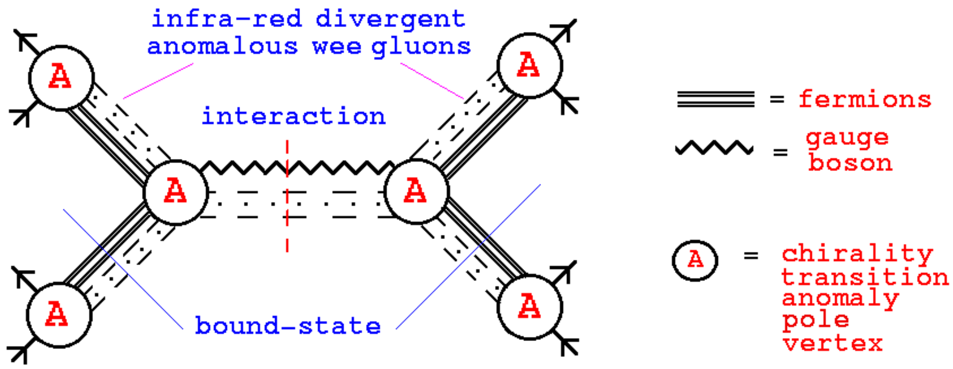
It is vital for S-Matrix symmetry breaking *that an anomaly pole connects*

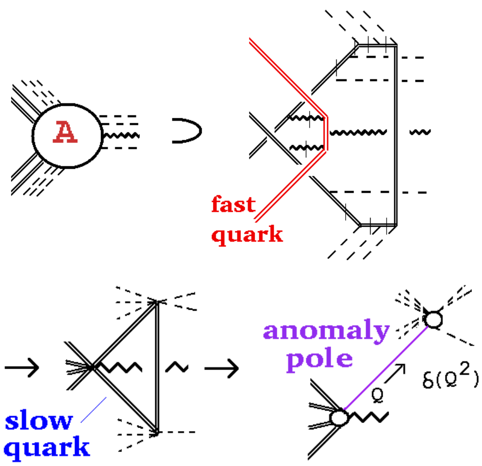
1. *a physical fermion pair* **+** *wee gluon "vacuum component"* $\leftrightarrow$ *Reggeon state with color zero projection* $\longrightarrow$ **finite perturbative interactions,** *&* {via the interaction}
2. *an opposite chirality fermion pair* - *one unphysical & with zero momentum.* $\leftrightarrow$ **pseudoscalar Goldstone boson*** *associated with symmetry breaking.*

Effectively, an anomaly pole bound−state is created by a zero momentum shift of the Dirac sea. By absorbing anomalous wee gluons, a physical fermion makes a symmetry−breaking chirality transition to an unphysical "hole state".

$*$ An ∞−momentum anomaly pole has physical Goldstone boson couplings.

The simplest DTR amplitudes selected by the anomalous wee gluon divergence. $\longleftrightarrow$





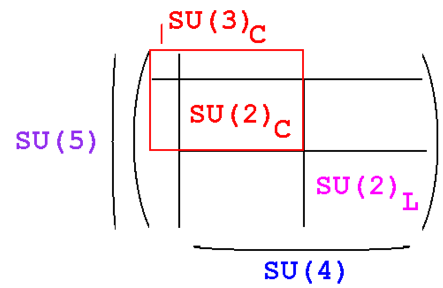
= **WEE GLUON ANOMALY COLOR FACTOR <-> sum over all wee gluons coupling to the slow quark loop**

anomaly pole factorization ↗ ↘

$\Longrightarrow$ in QUD the $\mathbb{P}$ will couple more strongly to sextet states than to triplet states

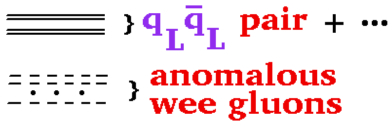
= **PERTURBATIVE COUPLING <-> QCD ADDITIVE QUARK MODEL**

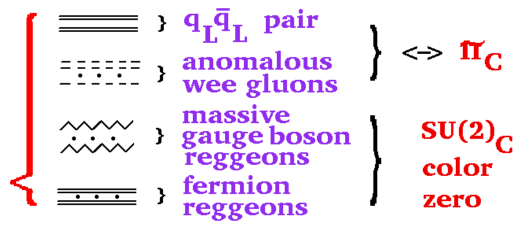
Restoration of SU(2)$_C$ - *gives anomaly pole chiral Goldstones (π_C's) due to $5 \oplus 5^*$ chirality transitions, that are $q\bar{q}$ ("mesons") or qq & $\bar{q}\bar{q}$ ("nucleons").*



The q's are **3's, 6's,** *&* **8's** *under SU(3)$_C$.* **8's** *are real wrt SU(3)$_C$, but contain complex chiral doublets wrt SU(2)$_C$. Via chirality transitions, the π_C's are also reggeon states*

$$\pi_C = q_L\bar{q}_R - \bar{q}_L q_R \longrightarrow$$

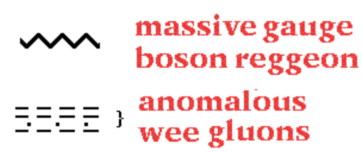




- *Other reggeon states containing a π_C are also selected {will give leptons & SU(5) symmetry}*

To avoid fermion loop exponentiation of the anomaly divergence **the massive gauge boson reggeons must be vectors** $\leftrightarrow$ *SU(2)$_C$ singlet gluons or photons.*

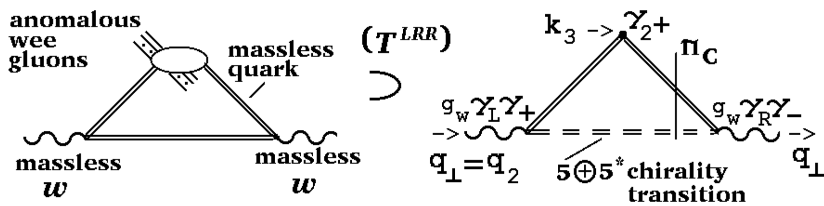
Interactions *are even signature & are SU(2)$_C$ singlet massive vector exchange, together with anomalous wee gluons* $\longrightarrow$



- *Massive SU(3)$_C$ gluon exchange in the SU(2)$_C$ wee gluon background* $\leftrightarrow$ $\mathbb{P}$ *.*
- **The massive gluon can be replaced by a massive γ, $W^{\pm}$ or Z^0.**

Elementary left-handed exchanges ($W^{\pm}$ & Z^0) exponentiate to zero, **but**

5$\oplus$5* chirality transitions $\longrightarrow$ crucial wee-gluon interactions.



$\sim \dfrac{g_w^2 \varepsilon_{+-23} k_3 q_2^2}{q_\perp^2} = g_w^2 k_3$

$\longrightarrow$ **mass** $= M_W^2 \sim g_W^2 \int dk k$ $\leftrightarrow$ **universal wee gluon integral.**

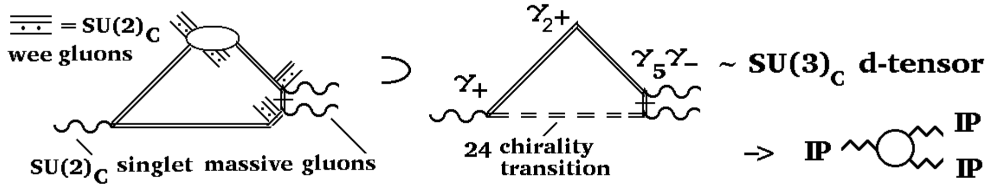
$\leftrightarrow$ **mixing** *with the $\pi_C{}'s$* $\{ \pi_6$ **dominates after SU(3)$_C$ is restored** $\}$

$\longrightarrow$ **new quantum number** $\{\longrightarrow$ *sextet flavor*$\}$ *&* **no exponentiation to zero.**

$\longrightarrow$ **massive vector** $W^{\pm}$ & Z^0

Odd-signature interactions are $\gamma\mathbb{P}$, $W^{\pm}\mathbb{P}$ & $Z^0\mathbb{P}$ $\{\rightarrow$ **physical γ, W$^{\pm}$, Z^0 after SU(3)$_C$ restoration**$\}$.

24 chirality transitions
$\longrightarrow$ d-tensor triple $\mathbb{P}$ vertex.



- *Wee gluons* $\longrightarrow$ *orthogonal γ-matrices* $\leftrightarrow$ γ_5.

  $\longrightarrow$ **essential vertex for the SU(3)$_C$ interaction & the Critical $\mathbb{P}$.**

SU(4) Restoration $\longleftrightarrow$ SU(2)$_C$ singlet vector γ_4 becomes massless

- *Other gauge bosons (that become massless) have left-handed couplings & appear only in interaction kernels* $\{$*reggeon diagrams are exponentiated to zero.*$\}$
- *γ_4 pairs have 1) even signature, 2) an SU(4) singlet projection, & 3) exponentiate to zero all amplitudes* **except when coupling to anomaly poles.** $\{\leftrightarrow 1-e^{-\infty}\}$
- *Anomalous wee bosons* $\{$*γ_4 pairs + SU(2)$_C$ anomalous wee gluons*$\}$

  $\longrightarrow$ *even signature γ - with SU(4) singlet projection.*
- *Anomalous wee bosons + massive gluon* $\longrightarrow$ **Supercritical $\mathbb{P}$.**

Pseudoscalar anomaly poles *coupling to γ_4 pairs are produced by*

1. *lepton pairs* *(1, 2, $\frac{1}{2}$) & (1, 2, -$\frac{1}{2}$).*

   Chiral symmetry + **24** *chirality transitions* $\longrightarrow$ **pseudoscalars** $\pi_L^{\pm,0}$

2. *SU(2)$_C$ singlets* *(8, 1, 1) & (8, 2, -$\frac{1}{2}$).*

   Chiral symmetry + **5**$\bigoplus$**5*** *chirality transitions* $\longrightarrow$ **pseudoscalars** $\eta_8^{\pm,0}$.

Now, the anomalous wee boson divergence $\Longrightarrow$ **physical bound-states**

1. **contain two pseudoscalar anomaly poles** *coupling to the divergence*
2. **have SU(4) singlet projections** *as reggeon states.*
3. **Fermion bound-states** *contain an additional elementary fermion.*

Leptons - π_L + π_8 + *additional lepton* $\longrightarrow$ *3 lepton generations.*

Hadrons - $\pi_{3,6}$ + η_8 $\longrightarrow$ *mesons* , + *additional quark* $\longrightarrow$ *baryons.*

$\{$*More details after SU(5) restoration.*$\}$

SU(5) Restoration $\leftrightarrow$ *SU(4) singlet vector becomes massless.*

1. **Supercritical $\mathbb{P}$** $\{\leftrightarrow \mathbf{SU(4)\ singlet + odd{-}signature\ anomalous\ wee\ bosons\ with\ SU(3)_C\ color}\}$ $\longrightarrow$ **Critical $\mathbb{P}$** $\{\leftrightarrow \mathbf{randomizing\ symmetry\ breaking\ ?}\}$
2. **Even signature anomalous wee bosons** $\{\mathbf{with\ SU(3)_C\ color\ zero}\}$

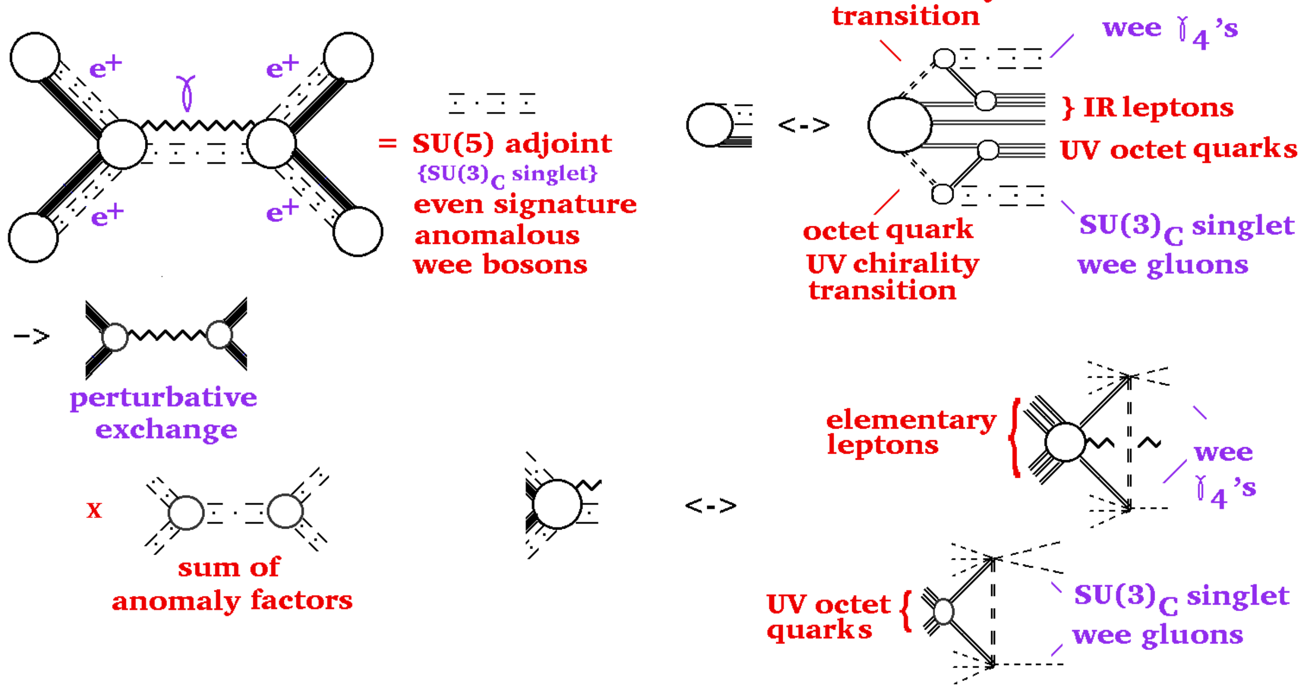
   $\longrightarrow$ **odd-signature massless γ & massive $W^{\pm},\ Z^0$.**
3. π_8 **&** η_8 **combine in real octet SU(3)$_C$ representation (Π_8)** $\Longrightarrow$
   - **octet IR anomaly poles cancel in all amplitudes,**
   - **UV Π_8 poles appear as $\lambda_\perp \to \infty$** $\{\leftrightarrow \mathbf{Pauli{-}Villars\ subtractions}\}$

   $\Longrightarrow$ **Leptons & hadrons have IR components combined with UV Π_8 's.**
4. **Interactions are determined by IR components** - *with states expressed as physical reggeons with an SU(5) singlet projection.*
5. *UV* Π_8 *anomaly poles* $\Longrightarrow$ **IR fermions must be**

   $(\mathbf{2}, -\frac{\mathbf{1}}{\mathbf{2}})_{\mathbf{L}}$ *or* $(\mathbf{2}, \frac{\mathbf{1}}{\mathbf{2}})_{\mathbf{R}}$ *or* $(\mathbf{1}, \mathbf{1})_{\mathbf{L}}$ *or* $(\mathbf{1}, -\mathbf{1})_{\mathbf{R}}$ $\{SU(2)\otimes U(1)\}$

$\Longrightarrow$ **IR components of leptons & hadrons form SM generations.**

First approximation in QUD



Octet quarks coupled via SU(3)$_C$ color zero anomalous wee gluons

$\{$contained in SU(5) adjoint even$-$signature anomalous wee bosons$\}$

provide a UV light-cone contribution in all states & vertices.

The SU(3)$\times$SU(2)$_L$$\times$U(1) lepton content, expressed as multi-fermion states, is

- $(e^-,\nu) \;\leftrightarrow (1,2,-\frac{1}{2}) \times \pi_L^0 \times \Pi_8$

  $\leftrightarrow \;\; (1,2,-\frac{1}{2})\times(1,2,-\frac{1}{2})(1,2,\frac{1}{2})\times(8,1,1)(8,2,-\frac{1}{2})$

  $\leftrightarrow \;\; \mathbf{SU(5)\ singlet/adjoint} - \mathbf{45^*\times 45^*\times 5\times 40\times 45^*}$

- $(\mu^-,\nu) \;\leftrightarrow (1,2,\frac{1}{2}) \times \pi_L^- \times \Pi_8$

  $\leftrightarrow \;\; (1,2,\frac{1}{2})\times(1,2,-\frac{1}{2})(1,2,-\frac{1}{2})\times(8,1,1)(8,2,-\frac{1}{2})$

  $\leftrightarrow \;\; \mathbf{SU(5)\ singlet/adjoint} - \mathbf{5\times 45^*\times 45^*\times 40\times 45^*}$

- $(\tau^-,\nu) \;\leftrightarrow (1,2,-\frac{3}{2}) \times \pi_L^+ \times \Pi_8$

  $\leftrightarrow \;\; (1,2,-\frac{3}{2})\times(1,2,\frac{1}{2})(1,2,\frac{1}{2})\times(8,1,1)(8,2,-\frac{1}{2})$

  $\leftrightarrow \;\; \mathbf{SU(5)\ singlet/adjoint} - \mathbf{40\times 5\times 5\times 40\times 45^*}$

$e^+,\ \mu^+,\ \tau^+$ *can be obtained via charge conjugation.*

QCD within QUD - the states are

1. **triplet mesons & baryons**
2. **sextet "pions" & "nucleons" (P_6 & N_6)**
3. **no** *hybrid sextet/triplet quark states*
4. **no** *glueballs.*

Consistent with, but fewer states than just confinement & chiral symmetry breaking.

- *Sextet pions* $\rightarrow$ $W^{\pm}$ & Z^0 $\Longrightarrow$ *sextet nucleons are the* **only new states.**
- *Sextet quarks have zero current mass* $\Longrightarrow$ N_6 **is stable** $\rightarrow$ **DARK MATTER**

  $\{$*electric charge* $\Longrightarrow$ P_6 *is heavier - in contrast to the triplet sector*$\}$
- **Critical $\mathbb{P}$ & parton model,** $\longleftrightarrow$ **no BFKL pomeron & no odderon.**

Compared to conventional QCD, the states are fewer & the interaction is simpler - in agreement with experiment !!

N_6**'s** *have a very strong, very short range, QCD self-interaction* $\{\rightarrow$ *clumps?*$\}$ *& a QCD interaction with normal matter only at UHE.* N_6 *production will dominate UHE x-sections & early universe stable matter formation (& explain the CR knee!)*

The bound-state mass spectrum will involve a combination of effects.

1. *Perturbative reggeization is a very small effect, since α_{QUD} is so small.*
2. **Wee gluon anomaly interactions** $\{\textbf{which need to be catalogued}\}$ **will mix** *the reggeon states & introduce anomaly color factors.*
3. The SU(3) strong interaction will be emphasized by both **color factors & by the resulting high mass sector.** Electroweak charges will also play a role.
4. **There is no symmetry that would conflict with the SM mass spectrum.**

A wide range of scales should emerge & in bound-states **all fermions will, effectively, have constituent masses.** *Connecting the η_6 to top production suggests*

$$m_{q6} \sim m_{top} \implies m_{N_6} \sim 500\, GeV$$

In general, a better understanding of anomaly interactions & related wee gluon distributions is needed to determine if, & how many, parameters are involved.

Presumably, CP violation can be introduced via the anomalies, but is it essential?

QUD Virtues $\{$*beyond QCD*$\}$

It would be hard to over-emphasize the scientific $\{$& aesthetic$\}$ importance of an underlying massless field theory for the Standard Model. In addition,

1. *QUD is self-contained - with only SM Interactions !!*
2. *The only new physics is the strong interaction sextet sector - giving* **EW symmetry breaking, dark matter,** *& unification without supersymmetry !!*
3. *The parity properties of the strong & weak interaction are naturally explained.*
4. *Particles & fields are truly distinct. Hadrons & leptons have equal status.* **No** *off-shell amplitudes &* **no** *Higgs field $\longleftrightarrow$ all symmetries & masses are S-Matrix properties.*
5. *The QUD S-Matrix could be the only "non-perturbative" part of field theory needed - with infinite momentum physics retaining a "perturbative" diagrammatic description.*
6. *Anomaly interactions mix the reggeon states &, presumably, introduce parameters.*
7. *Anomaly color factors should produce a wide range of scales & masses that could produce the SM spectrum - there is no conflicting symmetry.*
8. **Small neutrino masses** *should be due to the underlying small coupling.*
9. *There is no proton decay, but the* **SU(5) Weinberg angle should hold!**
10. *Perturbatively, QUD is an asymptotically free, massless, fixed-point theory that should have no perturbative renormalons $\Longrightarrow$ it has no vacuum energy & would induce Einstein gravity with zero cosmological constant.*